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STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

Research Investigation 87-5
Work Plan No. 83-S-27

Subject

The minus 0.02 mm size fraction in granular materials used in Vermont roadway and bridge construction.

Purpose

To evaluate the significance of the percent of material finer than 0.02 mm on frost susceptibility of granular materials used during the 1983 construction season.

Materials & Procedure

Thirty samples consisting of Sand Borrow, Granular Borrow, Subbase of Gravel, and Subbase of Crushed Gravel were collected from 29 sources and tested for gradation using a standard bank of sieves. The material passing the No. 10 sieve was then tested using a hydrometer to determine the percent of total sample finer than 0.02 mm (medium silt). Semi-log plots were constructed of the grain size distributions and coefficients of uniformity were calculated to determine grading of the sample materials. A plot of "percent particles finer than 0.074 mm" versus "percent particles finer than 0.02 mm", as shown on Figure 1, was made to show the sample distribution of frost susceptible material. The 0.074 mm size (No. 200 sieve) was used for comparison since this is the finest fraction tested under current Standard Specifications, and is also an indicator of frost susceptibility.

Background

Some of the earliest work on frost heave susceptibility by Casagrande (1931) identified the 0.02 mm size fraction as an important indicator of frost susceptibility. It was determined that a very uniform soil was frost susceptible when the percentage of particles finer than 0.02 mm was greater than 10 percent or greater than 3 percent in a non-uniform soil. Casagrande observed no ice segregation in soils with less than 1 percent of grains finer than 0.02 mm; even when the ground water was as high as the frost line.

More recent work by Esch, McHattie and Conner (1981) concluded that the best asphalt pavement performance occurs when the base and subbase layers contain less than 3 percent of particles finer than 0.02 mm and less than 6 percent of particles finer than 0.075 mm. Conversely, poor performance may be expected when percentages exceed 7 and 11 percent of particles finer than 0.02 mm and 0.075 mm respectively. (See Figure 1). Their laboratory experiments indicated that the best pavement performance occurs when heave rates, due to frost action, do not exceed 3 mm/day.

Another study by Vinson, Ahmad and Rieke (1986) set less conservative limits on the allowable percentages of "fines" in granular materials needed to maintain good roadway performance. Using the same heave rate of 3 mm/day as a point of comparison, corresponding values for percent particles finer than 0.02 mm and 0.074 mm were obtained from Figure 2. The values, 5.5 percent finer than 0.02 mm and 6.7 percent finer than 0.074 mm, are plotted on Figure 1 along with the limits suggested by Esch, McHattie and Conner.

Summary Of Results

The samples tested were all well-graded, having an average coefficient of uniformity of 47.1. Of the 30 samples plotted on Figure 1, 25 are within the "best performance" of Esch, McHattie and Conner, 3 samples lie in the intermediate area, and only two fall within the "poor performance" zone. All of the samples are below the 3 percent passing the 0.02 mm limit set by Casagrande for well-graded material. The curve shown on Figure 1 indicates that as the amount of material finer than 0.074 mm increases, there is a corresponding increase in the particles finer than 0.02 mm, up to approximately 5 percent finer than 0.074 mm. From this point, the relationship is less defined. As the percent finer than the 0.074 mm continues to increase from 5 percent, the amount of material finer than 0.02 mm remains approximately the same.

Recommendations

Overall, it appears that Vermont aggregate sources used during the 1983 construction season have low frost susceptibility. While 30 samples is not a representative data base for the State of Vermont, the data does show a good clustering in the zone of "best performance". Therefore, in the case of the data on hand, if the amount of material passing the No. 200 sieve (0.074 mm) does not exceed 6 percent as per Vermont Standard Specifications, then the particles finer than 0.02 mm are not a serious consideration. The 0.02 mm and finer size fraction appears to be well below levels which cause ice segregation and frost susceptibility in well-graded aggregates.

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References

Casagrande, A., "Discussion Of Frost Heaving", Highway Research Board, Proceedings, Vol. 11, p. 168-172, 1931.

Esch, D., McHattie, R. and Conner, B., "Frost Susceptibility Ratings And Pavement Structure Performance", in Frost Action And Risk Assessment In Soil Mechanics, Transportation Research Record 809, p. 27-34, 1981.

Vinson, T., Ahmad, F. and Rieke, R., "Factors Important To The Development Of Frost Heave Susceptibility Criteria For Coarse-Grained Soils", 65th Annual Meeting of the Transportation Research Board, Washington, D.C., 28 p., 1986.

Figure 1

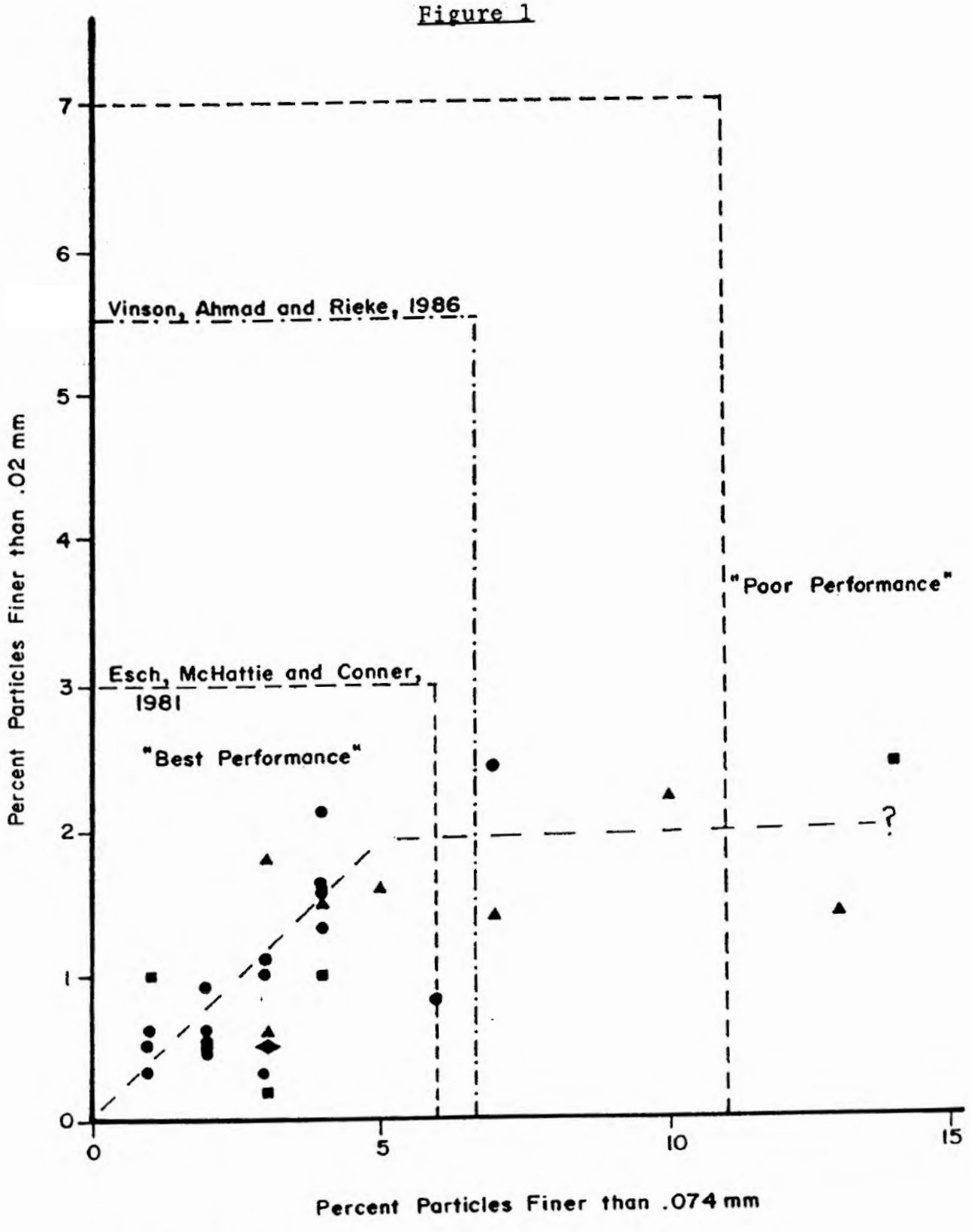
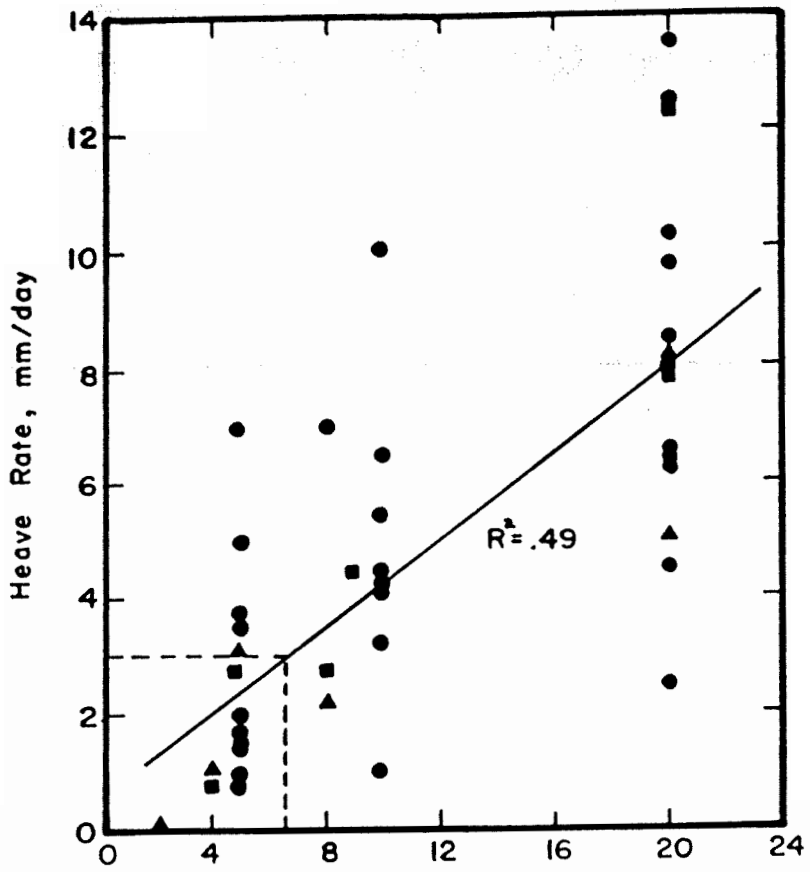

Vinson, Ahmad and Rieke, 1986
Esch, McHattie and Conner, 1981
"Best Performance"
"Poor Performance"
?
Percent Particles Finer than .02 mm
Percent Particles Finer than .074 mm
0
1
2
3
4
5
6
7
0
5
10
15
Subase of Gravel
Subase of Crushed Gravel
Granular Borrow
Sand Borrow

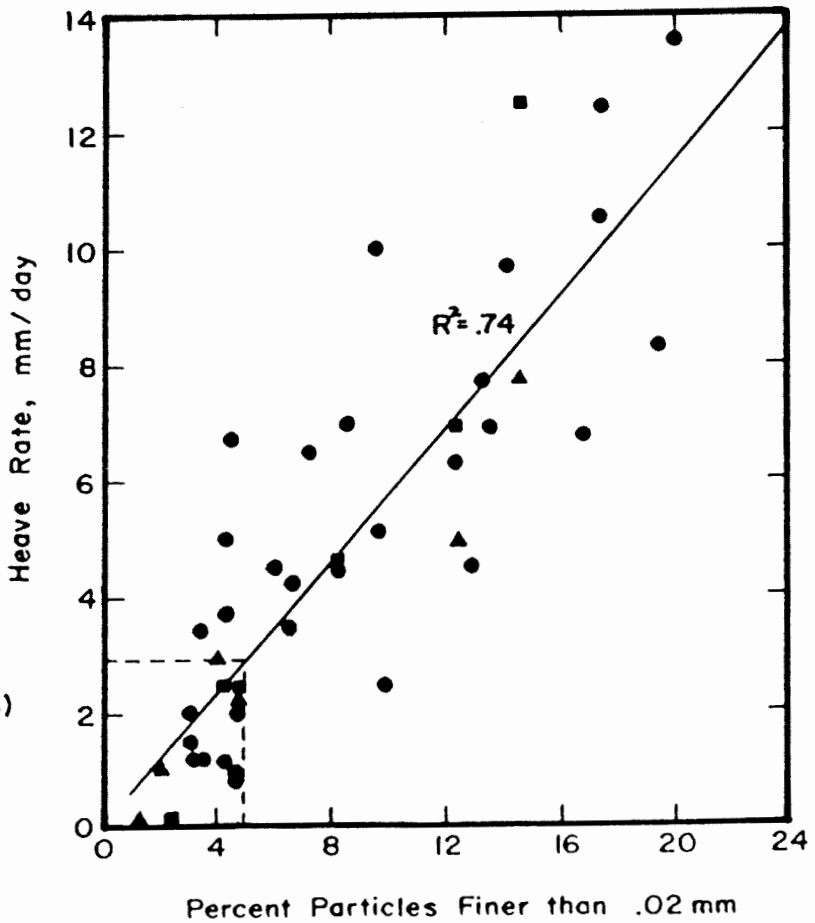
Figure 2a



LEGEND

- ● Uniform Sand + Fines
- ▲ Well Graded Crs. Sand + Fines
- ■ Pea Gravel + Fines

Figure 2b



From: Vinson, Ahmad and Rieke (1986)